Title	TRANSITION OF CRACK PATTERNS IN QUASI-STATIC FRACTURE(Session IV : Structures & Patterns, The 1st Tohwa University International Meeting on Statistical Physics Theories, Experiments and Computer Simulations)
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Citation	物性研究 (1996), 66(3): 582-583
Issue Date	1996-06-20
URL	http://hdl.handle.net/2433/95765
Right	
Type	Departmental Bulletin Paper
Textversion	publisher

TRANSITION OF CRACK PATTERNS IN QUASI-STATIC FRACTURE

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1. Introduction

How the cracks propagate when something is broken? Crack propagations are classied by their speed. One is fast crack and the other is slow crack. In the former crack speed is increasing in time and reaches at the order of sound speed of the material. This type of fracture is familiar and is important in engineering applications.

On the contrary the latter propagates much slowly and quasi-static. The criterion for the crack propagation was theoretically proposed by A.A.Griffith in 1920. Though this theory deals with fracture under static condition, the studies after Griffith mainly concerned the fast cracks. Though M.Hirata found morphological change of slow crack, there has been not much experimental studies on slow cracks. We made controlled experiments, and confirmed that a quasi-static fracture can exhibit a drastic change in morphology when the control parameter is varied.

Recently, theories and numerical studies are proposed which explain our experiments. We make detailed comparison between experiments and theories.

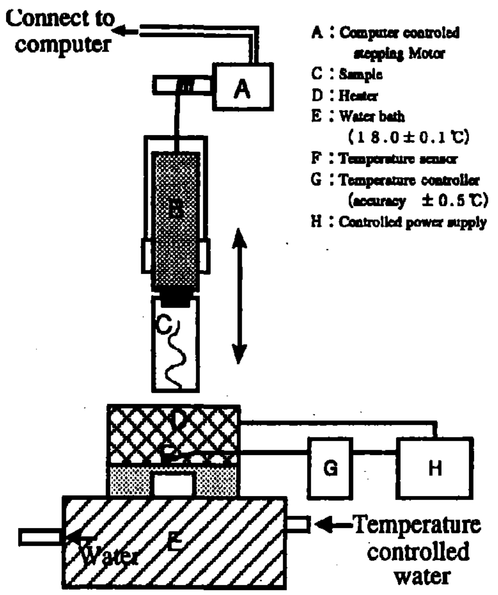

Fig. 1 Experimental setup

2. Experimental Set Up

Fig.1 shows the set up. We use thin glass plates as samples which have small flaw in the center of the bottom end. A sample is heated up in the heater several minutes and then slowly descended into the cooling bath. The sample is cooled suddenly and crack propagate near the surface of the water.

Control parameters are temperature difference ΔT and descent speed v. Thermal proportion is determined by ΔT and v. The thermal diffusion length l is derived by the thermal diffusion equation. The experimental condition is that the thickness of sample t is much small enough compared with thermal diffusion length l (t<<l) and l is smaller than the sample width W (l<W).

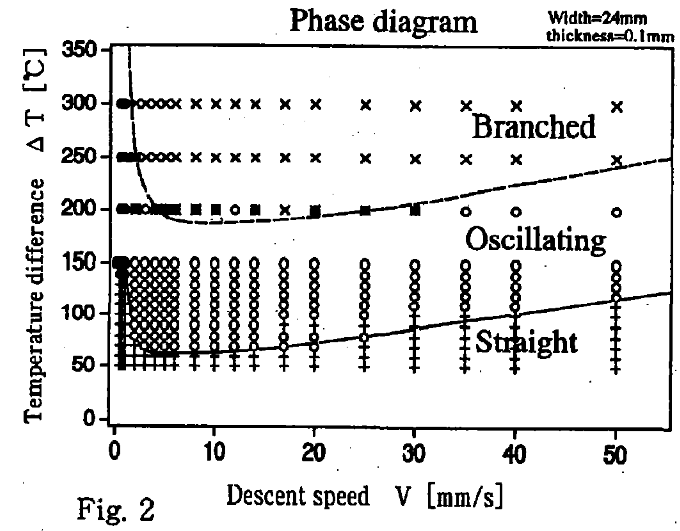

Fig. 2

3. Results

Our experimental system is simple. But it makes various types of crack patterns when we varied control parameters. We classify these crack patterns into three patterns. The first one is the straight crack which means that its crack pattern is finally straight line. The second is oscillating crack : a oscillating crack pattern goes on infinitely. Last one is branched crack : crack pattern has more than one branchings.

We varied control parameters ΔT and v to get a phase diagram. Fig.2 shows the phase diagram. Two lines in Fig.2 are transition lines. Solid line is a transition line from straight crack to oscillating crack and dotted line is from oscillating crack to branched crack. In this experiment, the sample width W is fixed.

Here, we introduce nondimensional parameters R and μ . R is proportional to ΔT and μ is in inverse proportion to v.

$$R = \alpha \Delta T E W^{1/2} / K_I^{C}$$

$$\mu = v W / \kappa$$

By using nondimensional parameter R and μ, we can plot different set of data for different samples in a single phase diagram.

Fig.3 shows the phase diagram by using R and μ . Two lines in Fig.3 show transition lines from no crack to straight crack and from straight to branched crack. These lines are calculated by the theory proposed by Sasa, Sekimoto, and Nakanishi. The theory agree with our experimental result.

We aslo did detailed experiments near the transition line from straight crack to oscillating crack. We fixed descent speed v, and changed temperature difference ΔT with small steps. The result is shown in Fig.4. It shows that there is the critical temperature difference ΔTc and if ΔT is larger than ΔTc, the crack is oscillating with finite amplitude. We can fit this curve by $(\Delta T\text{-}\Delta Tc)^{1/2}$.

What determine the wave length of the oscillation? Recently, M.Adda-Bedia and Y.Pomeau proposed their theory. In the theory they introduced parameter P which is in inverse proportion to μ . This theory predicts that the wavelength of oscillating crack λ depends on P. We measured λ in order to decide how does λ depend on P. Our result is shown in Fig.5. It shows that their theory agree with our experimental result qualitatively, but not quantitatively.

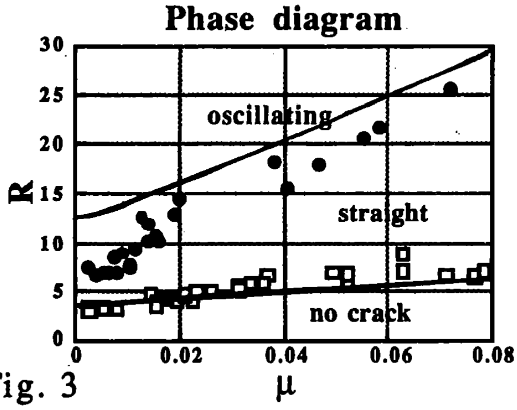

Fig. 3

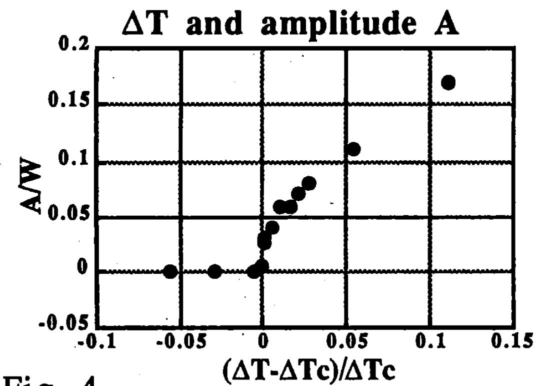

Fig. 4

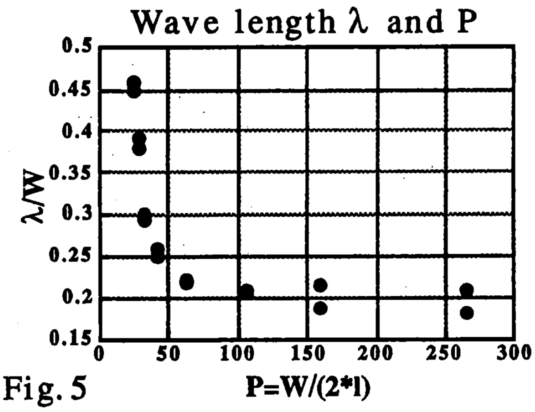

Fig. 5

4. Conclusion

1) We classify crack patterns into three and obtain phase diagram as a function of R and μ .
2) We confirm that the amplitude of oscillating crack is proportional to $\{(\Delta T\text{-}\Delta Tc)/\Delta Tc\}^{1/2}$.
3) We confirm that the wave length depend on μ .
4) Experimental results agree with proposed theories qualitatively.